DRAFT FOR DISCUSSION MAY 18, 2000

A Summer Study on the Future of Particle Physics

Chris Quigg[1]

The Division of Particles and Fields and the Division of Physics of Beams, units of the American Physical Society, propose to organize in 2001 a Summer Study on the Future of Particle Physics.

We will undertake an inclusive survey of the current state of particle physics and develop a thematic summary of goals of our field over the next two decades. We will explore a wide range of instruments that might enable us to address the important issues, and examine broad experimental programs that will be needed to advance our science. We hope to develop within the community a collective awareness of where we want to go in scientific terms; of the costs, benefits, and technical risks of accelerators we may soon be able to propose; and of what it will take to develop ideas that are not yet ripe to be judged.

The community represented in the DPF and DPB last gathered in 1996 to consider new directions for particle physics, with an emphasis on the high-energy frontier. A decade has passed since the last broad summer study of the state of particle physics and opportunities for the future. The Report of the DPF Committee on Long-Term Planning, *Particle Physics – Perspectives and Opportunities,* appeared at the end of 1994. It is now time to take stock of the new possibilities for particle physics, not only in experiments at the highest energies, but also in experiments of exceptionally high sensitivity; not only in experiments that use accelerator beams, but also in experiments that exploit natural sources; not only in the conceptual framework of theory developed hand-in-hand with experiment, but also with an eye to long-term ambitions for a more comprehensive theoretical paradigm.

[1]Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, Illinois 60510; Telephone +1 630.840.3578, Facsimile +1 630.840.5435, E-mail quigg@fnal.gov

We envisage a summer study of three weeks' duration that will attract approximately 450 accelerator physicists, experimenters, and theorists from the entire U.S. community. We hope that significant work will go on before the summer study, not only under the banner of existing groups dedicated to specific projects, but also in the context of working groups formed for the summer study itself.

Although the principal purpose of this summer study is for the particle physics community in the United States to examine and develop options for its future, we plan for significant involvement of physicists from abroad.

Historical Context

Snowmass '96 was organized in the wake of the cancellation of the Superconducting Super Collider, which had been assumed for a decade to be the next great center of particle physics in the United States. Although the Large Hadron Collider at CERN was well launched, congressional support for American participation in the LHC accelerator and experiments was not yet secure. The Fermilab Main Injector, the SLAC B Factory, and Phase III of the Cornell Electron Storage Ring were in prospect, but not yet in hand. Snowmass '96 was chartered to consider the United States program beyond these three projects in the context of the international high-energy physics program, particularly the LHC program.

The stated goals of Snowmass '96 included providing an opportunity for individuals interested in different future accelerators to interact with each other in order to provide a common understanding of accelerator and particle physics issues, develop a common understanding of the capability of possible future machines to address important physics issues, and start to build a consensus for the future United States program.

The 1996 summer study stimulated a great deal of significant work on accelerator technology and scientific impact alike. A feasibility study for a $\mu^+\mu^-$ collider received close attention. The promise of very high luminosity running of the Tevatron was presented for the first time to the wider community. The physics and technology of the Next Linear Collider was examined

in a number of documents, including the Zero-Order Design Report for the NLC. Snowmass '96 also brought together people interested in a "Really Large Hadron Collider," who examined a number of approaches to energies beyond the LHC. For the LHC itself, physics studies explored not only its discovery potential, but also the prospects for precision measurements.

The 1996 summer study was less successful at promoting mixing among interest groups, and it cannot be said that any consensus emerged about the next step for a major machine in the U.S.

Much has changed in the past four years. American physicists and institutions are now deeply integrated into the LHC project and experiments. The Fermilab Main Injector has been commissioned and run for fixed-target physics and is now being prepared for "Run 2" of the Tevatron Collider, to begin March 1, 2001. The SLAC B factory and the BaBar detector are off to an excellent start, with first physics results anticipated by Summer 2000. At Cornell, experimenters have begun taking data in the CLEO III detector, and the CESR III upgrade is largely complete.

The projects explored at Snowmass '96 have also evolved significantly. Fermilab is committed to an extended run of the Tevatron Collider that would accumulate more than 15 fb^{-1} by about 2007. The worldwide projects toward a linear collider have made important progress. In the United States, the NLC design produced at SLAC has been given a rigorous review in advance of proceeding to a conceptual design. Fermilab accelerator scientists have now joined the NLC design effort. A technical design report for DESY's superconducting linear collider, TESLA, is expected before the end of this year. The idea of a high-energy linear collider powered by a low-energy, high-current beam that has been pursued at CERN in the context of the CERN Linear Collider (CLIC) project, has made important headway at CERN and SLAC. The international collaboration considering the feasibility of a muon collider has reoriented itself toward a first goal of designing a high-intensity neutrino factory based on a muon storage ring. The Snowmass '96 activity on a Really Large Hadron Collider has become the VLHC (very large hadron collider) collaboration. All the projects discussed in the 1996 summer study have taken on increased definition and attracted new interested parties.

There have also been exciting developments in experimental physics.

Among several indications for neutrino oscillations, the most striking is the zenith-angle dependence of the atmospheric ν_μ rate reported by the Super-Kamiokande experiment. The KTeV and NA-48 experiments have demonstrated the presence of direct CP violation in $K_{\rm L} \to \pi\pi$ decays. The electroweak theory has survived numerous stringent tests (at the 10^{-3} level); within the standard electroweak theory, precision measurements from LEP, SLD, CDF, DØ, and NuTeV point to the need for a light Higgs boson. Quantum chromodynamics has become ever more secure as the theory of the strong interactions, capable of precision ($\sim 1\%$) calculations in many situations important to experiment.

In the realm of theory, there has been extensive development of scenarios for breaking supersymmetry amd a huge leap in understanding nonperturbative phenomena in supersymmetric gauge theories. New ideas about dynamical symmetry breaking have moved to the fore, including some that ascribe a special role to the top quark. The notion of string duality is changing our basic conceptual understanding of gauge theories, gravity, spacetime, and quantum dynamics. Fascinating speculations have emerged about the possibility that collider experiments may have direct sensitivity to the existence and character of extra spatial dimensions, and of quantum gravity.

Goals of the 2001 Summer Study

We conceive of the summer study as a very inclusive gathering, not narrowly focused on one machine or a set of machines, but devoted to the field of particle physics broadly understood. Our first order of business is to (re)constitute the community as we prepare ourselves to outline the future program, mindful of the choices we will make over the next few years about the next big machine. We seek to promote mixing among theorists, accelerator physicists, and experimenters, and mixing among different communities of interest. To that end, we encourage the participation of all who regard themselves as particle physicists.

Our program for the summer study includes the following explicit goals:

- Undertake a thematic survey of our vision of particle physics and its

future, in the most ambitious intellectual terms. Within this broad vision, identify the specific questions that can be addressed by experiment over the next two decades.

- Consider the range of instruments germane to achieving our scientific goals. Assess readiness, capabilities, cost, and technical risk. Compare U.S. efforts with those in the rest of the world. Prepare a comprehensive R&D plan to provide us with the options we will need in the near and far term.

- Understand the terms on which we should try to make national and international decisions about the next steps in accelerator-based particle physics.

- Investigate overlapping interests with other disciplines, in preparation for exploring interagency cooperation in the United States.

To capture the information developed for the summer study, we will produce three documents as a community:

1. A brief and illustrated thematic survey of what particle physics is and aspires to be, guided by the scientific imperatives.

   Comment: Documents proceeding from broad scientific goals to specific questions and then to instruments and technology development have been used to excellent effect by NASA. We will produce this survey in final form at the summer study (with work before, but it can't be a closed book before the community speaks) with professional help. It should exist in several formats (printed page, web site, seminar materials, etc.), and in versions for different audiences, including the physics community and the wider public. Among other things, the thematic survey will counter the false impression that all of particle physics is defined by one question or one accelerator.

2. A coherent accelerator R&D plan giving the needed work, time scales, and levels of effort required to bring us to the point of deciding about different future instruments.

Comment: This document can accomplish several important goals: it will provide a rich timeline of possibilities, with different and overlapping time scales; it will show the importance of preparing possible futures while acting in the present; and it offers all the project constituencies the chance to win something, instead of creating an all-or-nothing, either/or environment. Maybe we can even foster an atmosphere of "we are all in this together."

3. A more detailed, but still < 100-page "white paper" on the field in all its richness and potential.

   Comment: In the spirit of the 1994 Committee on Long-Range Planning Report, this document can capture our community's sense of itself. Organized around scientific and technical goals, rather than laboratory programs, it can serve as important backdrop for future policy decisions.

The work carried out for the 2001 Summer Study by individuals and working groups will be reported in "Snowmass" *Proceedings.* If various groups wish to contribute useful working documents or project status reports (as happened in 1996), it is easy to include those on a CD-ROM.

Past DPF/DPB Summer Studies

▷ 1982 DPF Summer Study on Elementary Particle Physics and Future Facilities, 28 June –16 July 1982, Snowmass, Colorado

▷ 1984 DPF Summer Study on the Design and Utilization of The Superconducting Super Collider (SSC), 23 June – 13 July 1984, Snowmass, Colorado

▷ 1986 DPF Summer Study on the Physics of the Superconducting Supercollider, 23 June – 11 July 1986, Snowmass, Colorado

▷ 1988 DPF Summer Study on High-Energy Physics in the 1990s, 27 June – 15 July 1988, Snowmass, Colorado

▷ 1990 DPF Summer Study on High-Energy Physics: Research Directions for the Decade, 25 June - 13 July 1990, Snowmass, Colorado

▷ 1994 DPF Summer Study on High-Energy Physics: Particle and Nuclear Astrophysics and Cosmology in the Next Millennium, 29 June – 14 July 1994, Snowmass, Colorado

▷ 1996 DPF/DPB Summer Study on New Directions for High-Energy Physics, 25 June – 12 July 1996, Snowmass, Colorado

Dates and Places for the 2001 Summer Study

Cynthia Sazama of the Fermilab Conference Office has secured offers from a number of resorts and conference centers. The traditional location of Snowmass, Colorado, is available to us from June 30 – July 21, 2001. Snowmass has offered reduced-cost housing for 50 students. Several other locations seem able to meet our needs.

Other Events in June – September 2001

Although we cannot eliminate every conceivable conflict, we should try to avoid dates that would draw many prospective participants away. The list below, culled from SPIRES and the CERN conference roster, reveals an unfortunate collision between the Snowmass opening and the EPS HEP conference in Budapest. George Mikenberg, acting for the European Physical Society, has asked that we avoid the Budapest meeting. I told him that we would do our best, but hoped that he and his colleagues would understand that the kind of conference space we require is in short supply, and it might be impossible to avoid interference. The Snowmass dates do not overlap the Particle Accelerator Conference or the Lepton-Photon Conference.

▷ 28th International Conference on Plasma Science (ICOPS 2001) and 13th International Pulsed Power Conference (IPPC 2001) 17 – 22 June 2001, Las Vegas, Nevada

▷ 2001 Particle Accelerator Conference, 18 – 22 June 2001, Chicago, Illinois

- ▷ International Meeting on Quantum Gravity and Spectral Geometry 2 – 6 July 2001, Naples, Italy
- ▷ 4th Edoardo Amaldi Conference on Gravitational Waves (Amaldi 2001) 7 – 12 July 2001, Perth, Australia
- ▷ International Conference on High Energy Physics of the European Physical Society 12 – 18 July 2001, Budapest, Hungary
- ▷ 16th International Conference on General Relativity and Gravitation (GR16) 15 – 21 July 2001, Durban, South Africa
- ▷ 2001 international Conference on Lepton–Photon Interactions 23 – 27 July 2001, Rome
- ▷ 9th International Symposium on Meson - Nucleon Physics and the Structure of the Nucleon (MENU 2001) 26 – 31 July 2001, Washington, District of Columbia
- ▷ 7th International Wigner Symposium (Wigsym 7) 24 – 29 August 2001, and Feynman Festival 22 – 23 August 2001, College Park, Maryland
- ▷ 6th International WEIN Symposium: A Conference on Physics beyond the Standard Model (WEIN 2001), 23 – 29 September 2001, Heidelberg, Germany
- ▷ European Conference of Applied Superconductivity 2001 26 – 30 August 2001, Copenhagen, Denmark
- ▷ 9th International Conference on the Structure of Baryons (Baryons 2001) 30 September – 6 October 2001, Newport News, Virginia

Next Steps

1. Refine this draft document into a clear statement of our motivation and broad goals.
   (a) Using the advice of the laboratory directors, the chair of HEPAP, and the laboratory users organizations, prepare a second draft;

   (b) Request comments from the DOE and NSF program offices to prepare a final draft;

   (c) Circulate the document to the DPF and DPB Executive Committees for final approval.

2. Prepare a proposal for support of the 2001 Summer Study, to be presented to the Department of Energy and the National Science Foundation.

3. Discuss with the laboratories the financial, equipment, and personnel support we will need from them.

4. Identify a steering committee representative of the community. The cochairs designated by DPF and DPB are Chris Quigg and Ron Davidson. My view is that the steering committee should present a mix of youth and experience, but that young physicists should take major responsibility for the individual study groups.

5. Select a site for the summer study, to be ratified by the DPF and DPB Executive Committees.

6. Report on the status of our plans at the DPF Meeting in Columbus and take input from the assembled community.

7. Hold a meeting of the steering committee in Columbus to lay out the organization of the summer study, identify topics for study, study groups, and convenors.

8. Announce the details of the organization early in the academic year, and encourage work before summer!